SECURITY INFORMATION

CIA TS No. 70438
Copy No.

CONFIDENTIAL

PROVISIONAL
~~ECONOMIC~~ INTELLIGENCE REPORT

A

THE PATTERN OF LAND USE IN RELATION TO TARGET GRAINS IN THE USSR AND THE PROBABLE SPREAD OF STEM RUST ON CEREAL GRAINS

The last three footnote references in the Abstract, p. 43, are to Part I, which is already approved by ORR.

D/R would appreciate your printing this final copy and returning it by 1000 hours, 22 Jan, or earlier if possible (to Room 2117 M).

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CIA/RR PR-
~~October~~ 1958
~~December~~
January

Part II of this report was prepared by the Office of Scientific Intelligence.

CENTRAL INTELLIGENCE AGENCY

OFFICE OF RESEARCH AND REPORTS

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NOTE ON CLASSIFICATION

The over-all classification of this report is TOP SECRET. The map and the Annex, however, are classified SECRET.

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FOREWORD

This report is in two parts. Part I deals with the relationship of the land-use patterns of the principal cereal grain-producing administrative districts in the biological warfare (BW) target regions of the USSR to the magnitude of local targets, in terms of vulnerable grain expressed as percentages of the total production of the USSR. Part II deals with the probable spread of stem-rust infection from foci of primary infection.

Part I is based on the latest Soviet acreage statistics available, those for 1938, a climatically normal year. The total acreage presently seeded to grain crops and its distribution by regions are still much the same. The 1938 pattern is therefore believed to be satisfactory for the purposes of this report, although the 1938 figures are only approximately applicable to present conditions and are subject to revision.

Part II is based largely on case histories of stem-rust spread from infected bushes in barberry in the US. The spread of infection from the more or less concentrated yet limited foci of barberry bushes bears a very uncertain relation to the spread of infection from the larger and originally more diffuse centers developing from feather-bomb drops. A great many factors are involved, and the data now available are not adequate to assess these factors. It is therefore impossible at present to calculate with accuracy the area in which a specified crop loss will occur as a result of stem-rust spread from a given successfully established infected area.

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THE PATTERN OF LAND USE IN RELATION TO TARGET GRAINS IN THE USSR AND THE PROBABLE SPREAD OF STEM RUST ON CEREAL GRAINS *

Summary

The surplus grain areas in the USSR in which growing grains may become biological warfare (BW) targets are located in the southern part of European USSR and in a narrow belt of Asiatic USSR extending eastward from the Ural Mountains to the Altai Mountains. In this report the surplus grain areas of European USSR are divided into three regions according to their principal crops: Region I, winter wheat** and barley; Region II, spring wheat**; and Region III-A, winter rye** and oats. From a statistical analysis of the land-use patterns and production of the target grains in the districts it is possible to indicate the degree of vulnerability of target grains in the districts and the statistical chance of making a direct hit with a single BW munition in European USSR. Statistically, the chances range from 4 percent in Groznyy Oblast of Region I to 58 percent in Nikolayev Oblast of Region I. Obviously, a BW attack would be more successful in those areas where the proportion of target grains is highest.

Complete and unqualified reliance should not be placed on the statistical approach to land use, because certain known physical features limit crop area and production in parts of every region. Thus the avoidance of mountainous or waste areas in a district with an over-all statistical chance of a direct hit of 28 percent (the average for Regions I, II, and III-A of European USSR) would increase the probability considerably. A study of aerial photographs should indicate some of these areas to be avoided. Certain qualifying factors are herewith considered in connection with the analysis of the statistics of land use.

** The terms "winter wheat" and "winter rye" are applied to varieties seeded in the fall and harvested during the following summer. Spring wheat and spring rye are seeded in the spring and harvested in the

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Because spring rye is a relatively unimportant crop in the USSR, it has not been included in the grain statistics of this report.

* This report contains information which should be disseminated to CIA as soon as possible.

in the USSR

A study of the famine that occurred in 1932-33 indicates that it is possible for a stem-rust epidemic to extend over parts of the southern grain surplus regions in European USSR. The same study shows that Soviet crop requisitioning for nonfarm uses and exportation remained unchanged in spite of famine and starvation on the country's farms.

Assuming that a BW attack is possible and that it can be directed toward areas of highest vulnerability, its success will depend on the extent of the rust-spread grids and the intensity of destruction within these grids of wheat, rye, barley, and oats in the grain surplus regions at the time of the attack.

Of 1,528 case histories of stem-rust spread from infected barberry bushes in the US, 132 cases showed damaging effect in excess of 1 mile from the focus of infection, and 28 cases were dramatic, with the spread ranging up to 2,260 square miles and with heavy damage occurring up to 250 square miles. A review of these cases, with their inherent and admitted limitations, shows positively that under a wide range of conditions as to terrain, geographic location, and season a destructive spread of varying extent will occur when a central source of inoculum is established. Research now complete indicates that "heavy" damage in excess of 100 square miles can be expected from each focus of stem-rust infection that is established under favorable conditions.

(End of summary)

PART I

PATTERN OF LAND USE IN RELATION TO [redacted] GRAINS IN THE USSR

A. Introduction.

There is no single pattern of land use in the USSR. There are nearly as many patterns of land use as there are oblasts, krays, and other administrative districts. For the cereal grains -- wheat, rye, barley, and oats -- these varying patterns are indicated by statistics for the seeding and production of these grains, district by district. In this report, statistics for seeding in a district are given as a percentage of the total area of the district seeded to the specified grains, and statistics for production in a district are given as a percentage of the total Soviet production of the specified grains.

The consolidation of such seeding and production statistics for cereal grains, which are all vulnerable to a certain strain of stem rust, serves to indicate the percentage chance of a direct hit being made by any single E-73 feather-bomb drop. It also serves to indicate the magnitude of local targets.

The last reliable official Soviet acreage statistics on the basis of small administrative districts are those of 1938. These data, which have been used by the US Department of Agriculture in plotting conventional dot maps to show the distribution of grains and other crops, are those on which the deductions made in this report are based. There are no official corresponding production statistics. The year 1938, however, was an average year with rather good growing conditions in North Ukraine but dry in South Ukraine. The customary spring drought crept up the Volga River, and, early in the summer, hot winds swept across the Caspian Sea, reducing what otherwise might have been a bumper crop.* On the whole, however, weather conditions

* The author of the land-use part of this report traveled through these regions in 1938 appraising the agricultural situation in the USSR for the US Department of Agriculture.

during the growing season, which largely determine yield, were about average. Therefore, in order to obtain an expression of quantity, or production, for each of the four cereal target grains in each oblast, kray, or other administrative district, the acreage seeded to each grain in each such ~~territory~~ district has been multiplied by the average yield of each grain for that ~~territory~~ district expressed in centners per hectare.* In Table 1,** production bases computed on the 1938 acreage are shown. All computations and, in some cases, estimates were adjusted to conform with 1950 boundaries.

While the data used in this report are based on the 1938 land-use patterns because 1938 is the last year for which published data are available on a detailed regional basis, it is believed that shifts in acreage during the past 14 years have not been sufficiently great to render the 1938 acreage and the computed production bases invalid for the purposes of this report. The total acreage seeded to grain crops is not materially different now from what it was in 1938, and distribution by regions is much the same. There have been some shifts among grains, such as a tendency to stress bread grains as against feed grains and to plant rye rather that wheat in some regions, but, generally speaking, these shifts have for the most part taken place within the potential target areas, the major grain surplus regions. Therefore, the 1938 pattern is still believed to be a realistic one. There has certainly been no shift in the weather pattern, and the use of average yields gives a basic picture of what may be expected under normal conditions as well as a point of departure for comparing the effect of annual fluctuations in weather and other growing conditions on production in other years.

In several treatises the vulnerability of Russian grain to BW attack has been analyzed in considerable detail, and certain potential target areas have been in-

* A hectare equals 2.47 acres, and a Soviet centner equals 220.46 pounds (or 3.67 bushels of wheat, 3.94 bushels of rye, 4.59 bushels of barley, and 6.89 bushels of oats).

** Table 1 follows on p. .

dicated. It is a matter of record that in 1938 the territories now comprising the USSR seeded 98.7 million hectares to the four cereal target grains — wheat, rye, barley, and oats — and that 74.8 million hectares, or 75.8 percent, were seeded in European USSR, while 23.9 million hectares, or 24.2 percent, were seeded in Asiatic USSR.

Under normal growing conditions the 75.8 percent of the total acreage of the USSR seeded in European USSR in 1938 would have accounted for 78 percent of all the cereal target grains produced in the USSR in that year, including 90 percent of the winter wheat, 49 percent of the spring wheat, 93 percent of the winter rye, 83 percent of the barley, and 76 percent of the oats (see Table 1). Likewise under normal growing conditions the acreage seeded in Asiatic USSR in 1938, 24.2 percent of the total, would have accounted for 22 percent of all the cereal target grains produced in the USSR in that year, including 10 percent of the winter wheat, 51 percent of the spring wheat, 7 percent of the winter rye, 17 percent of the barley, and 24 percent of the oats (see Table 1).

B. Regions of Production.

The grain surplus regions of the USSR are located in the southern part of European USSR and in a narrow belt of Asiatic USSR between the parallels of 45 and 55 degrees north latitude extending from the Ural Mountains eastward to the Altai Mountains. There are various ways of describing these European and Asiatic grain surplus regions in which growing grains may become logical targets for BW attack. If the attack is to be made with use of E-73 feather bombs which are carrying spores of rusts that will attack wheat, rye, barley, and oats separately or in combination, it is not necessary to consider separately the target potentialities of the area seeded to each grain. For the purposes of this report, European USSR has been divided into three regions based on land use (see the accompanying map)* as follows:

* Following p. 26, below.

Table 1

Target Grains: 1938 Computed Production Base of Winter Wheat, Spring Wheat, Winter Rye, Barley, and Oats in Specified Regions of the USSR

Region	Winter Wheat		Spring Wheat		Winter Rye a/		Bread Grain		Barley		Oats		Total	
	Metric Tons	Percent	Metric Tons	Percent	Metric Tons	Percent	Metric Tons	Percent	Metric Tons	Percent	Metric Tons	Percent	Metric Tons	Percent
European USSR														
Surplus Region I Winter Wheat, Barley	9,594.4	61.5%	917.6	5.1%	2,257.0	11.5%	12,769.0	24.0%	3,851.1	42.2%	1,657.1	10.2%	18,277.2	23.3%
Surplus Region II Spring Wheat	613.9	4.0%	4,971.0	27.7	3,116.6	15.8	8,701.5	16.3	1,039.3	11.4	1,593.5	9.9	11,334.3	14.4
Surplus Region III Rye, Oats	2,359.6	15.1%	1,547.0	8.6	5,915.0	30.0	9,821.6	18.4	928.3	10.1	3,195.8	19.8	13,945.7	17.7
European USSR Total Surplus Regions	12,567.9	80.6%	7,435.6	41.4	11,288.6	57.3	31,292.1	58.7	5,818.7	63.7	6,446.4	39.9	43,557.2	55.4
Deficit Region III	1,351.1	8.7%	1,387.1	7.7	7,015.9	35.6	9,754.1	18.3	1,698.0	18.6	5,758.2	35.6	17,210.3	21.9
Other Areas	178.7	1.1	20.6	0.1	45.9	0.2	245.2	0.5	72.5	0.8	64.6	0.4	382.3	0.5
Total European USSR	14,097.7	90.4	8,843.3	49.2	18,350.4	93.1	41,291.4	77.5	7,589.2	83.1	12,269.2	75.9	61,149.8	77.8
Asiatic USSR														
Asiatic Surplus Region Spring Wheat, Oats	27.7	0.2	6,030.1	33.6	1,046.7	5.3	7,104.5	13.3	368.5	4.0	2,547.1	15.8	10,020.1	12.8
Other Asiatic Regions	1,471.1	9.4	3,089.0	17.2	312.0	1.6	4,872.1	9.2	1,173.5	12.9	1,349.1	8.3	7,394.7	9.4
Total Asiatic USSR	1,498.8	9.6	9,119.1	50.8	1,358.7	6.9	11,976.6	22.5	1,542.0	16.9	3,896.2	24.1	17,414.8	22.2
Total USSR	15,596.5	100.0	17,962.4	100.0	19,709.1	100.0	53,268.0	100.0	9,131.2	100.0	16,165.4	100.0	78,564.6	100.0

a. Figures for bread grains are not included in the total.

Region I, in which winter wheat is the most important crop and barley is second in importance; Region II, in which spring wheat is the most important crop; and Region III, in which winter rye and oats are the important crops. The surplus only grain [redacted] region of Asiatic USSR, in which spring wheat and oats are the important crops, will be designated, for the purposes of this report, as Region IV (not shown on the map).

Ninety-nine of the varying land-use patterns of these regions are indicated in the tables of the Annex, The Statistical Basis Indicating the Land-Use Pattern and Distribution of Grain Production in Specified Administrative Districts of the USSR,* Tables 1 to 87, inclusive, being devoted to European USSR and Tables 88 to 99, inclusive, to Asiatic USSR. In each table the total area of each district is given, as well as the area seeded to each of the target grains -- winter wheat, spring wheat, winter rye, barley, and oats -- and the total area seeded to these target grains, together with the percentage that each such area is of the total area of each district. These percentages for European USSR are also indicated, in black, on the map [redacted] in each corresponding district that is shown. The tables in the Annex also give the production of each target grain and the total of these grains, as well as the percentage that each such production is of the total production of the corresponding grain in the USSR. These percentages for European USSR are also indicated, in red, on the map in each corresponding district that is shown.

* Following p. , below.

These regions show perceptible differences in land-use patterns, but, in reality, adjoining regions tend to merge and are not sharply delineated as indicated on the map for European USSR. For convenience, the broad characteristics of each region, [redacted].

1. Region I.

Region I is the winter wheat and barley region, a surplus region, of European USSR, including parts of West and North Ukraine, all of South Ukraine, the Moldavian SSR, Crimea, and the North Caucasus [redacted]. Winter wheat is the most important of the target grains in Region [redacted]. Winter rye is generally the second most important crop in West and North Ukraine, although barley follows winter wheat in order of importance in South Ukraine except in Voroshilovgrad and Stalino oblasts. Spring wheat is the least important target grain in this region.

Under normal growing conditions the acreage seeded in the potential target area*** of Region I in 1938 would have accounted for 23 percent of all the target grains produced in the USSR in that year (see Table 1). The region would have produced 62 percent of the winter wheat, 5 percent of the spring wheat, 12 percent of the winter rye, 42 percent of the barley, and 10 percent of the oats. Under normal growing conditions the bread-grain production of the potential target area of Region I in 1938 would have been 24 percent of the total bread-grain production in the USSR.

*The North Caucasus [redacted] comprises Krasnodar and Stavropol' krays, Groznyy Oblast, and Dagestan ASSR.

** Ismail Oblast (in South Ukraine), in which barley is the most important target grain, is the single exception.

*** In Region I, three districts lie outside the potential target area of a probable BW attack on grains: the Transcarpathian Oblast in the west and [redacted] Groznyy Oblast and Dagestan ASSR in the southeast.

in 1938 would have been 24 percent of the total bread grain production in the USSR.

Ninety-nine of the land-use patterns are indicated in the tables in the Annex, The Statistical Data Indicating the Land-Use Pattern and Distribution of Grain Production in the Specified USSR Districts. In each table the total area of each district is given, as well as each of the four grains — winter wheat, spring wheat, winter rye, barley, and oats — and the total area seeded to these four target grains, together with the percentage that each such area is of the total area of each district. These percentages are indicated in black on the map (following p.), and that is shown in each corresponding district. The tables in the Annex also give the production of each target grain and the total of these grains, as well as the percentage that each such production is of the total production of the corresponding grain in the USSR. These percentages are also indicated in red on the map.

In that part of the Ukraine which is included in Region I the statistical approach to the pattern of land use indicates that, for example, 58 percent of the total area of Nikolayev Oblast was seeded to the four cereal target grains (see the map and Table 13 in the Annex). The distribution of acreages in Nikolayev Oblast is fairly uniform. If it is assumed that the grain rust spores disseminated from a single E-73 feather-bomb drop have an initial spread of 10 square miles, it may be construed that some spores from a single feather-bomb drop in Nikolayev Oblast would have more than a 58 percent chance of hitting one or another of the four cereal target grains.

Conversely, as indicated on the map, the statistical chance of making a direct hit in the Transcarpathian Oblast in the extreme west of Region I is only 8 percent,

whereas in Groznyy Oblast, in the extreme southeast there is a statistical chance of only 4 percent and in Dagestan ASSR only 6 percent of making a direct hit. These districts, therefore, are not included in the discussion of Region I. It is obvious that an attempt at a BW attack on the grain growing in these districts would not be worth while.

There are three districts in Region I in which the statistical approach to land use is not directly valid. In the southern part of the Crimea there is a range of low mountains where the use of land for field-crop production is negligible. In the area north of these mountains the chance of making a direct hit is greater than the 28 percent indicated on the map for the Crimea Oblast as a whole.

The two other questionable districts in Region I are Krasnodar Kray and Stavropol' Kray. For example, Krasnodar Kray (see the map and Table 19 in the Annex) has a total area of 8.5 million hectares, of which only 2.4 million hectares, or 28 percent, were seeded to target grains in 1938. These target grains, however, are distributed throughout the general seeded acreage of only 3.8 million hectares, or 45 percent of the total area. The seeded area lies north of the Caucasus Mountains, which occupy 55 percent of the whole area of the kray. Outside the seeded area the land of the kray is occupied by orchards, meadows, pastures, and agricultural waste land. It is not possible at this time to delineate the land-use pattern within the limits of the total seeded area.

Stavropol' Kray (see the map and Table 30 in the Annex) has a total area of 7.66 million hectares, of which only 2 million hectares, or 26 percent, were seeded to target grains in 1938. These target grains, however, are distributed throughout the general seeded acreage of only 3.1 million hectares, or 41 percent of the total area, lying in the west-central part of the kray. A large percentage of the kray is occupied by the Caucasus Mountains to the

south and by arid wastes to the northeast. It is not possible at this time to delinate the land-use pattern within the limits of the total seeded area.

Although in each of the several oblasts of the Ukraine, as well as in the Moldavian SSR, the statistical approach to land use indicates in a rough way the chance of making a direct hit by an E-73 feather-bomb drop, an analysis of aerial photographs may indicate, in some instances, localities to be avoided in a bombing attack, thus increasing the chance of a hit.

2. Region II.

Region II is the spring wheat region, a surplus region, of European USSR, including the oblasts of Rostov,* Stalingrad, Saratov, Ul'yanovsk, Kuybyshev, and Chkalov and Bashkir ASSR. Spring wheat is the most important of the target grains in Region II. Rye is second in importance except in Rostov Oblast, where it gives place to both barley and winter wheat. Except in Rostov Oblast, winter wheat is an unimportant grain. Oats are relatively unimportant in Rostov and Stalingrad Oblasts but are third in importance in the northern oblasts. Barley is significant only in the south.

Under normal growing conditions the acreage seeded in the potential target area of Region II in 1938 would have accounted for 14 percent of all the target grains produced in the USSR in that year (see Table 1). The region would have produced 28 percent of the spring wheat, 4 percent of the winter wheat, 16 percent of the winter rye, 11 percent of the barley, and 10 percent of the oats. Under normal growing conditions the bread-grain production in the potential target area of Region II in 1938 would have been 16 percent of the total bread-grain production in the USSR.

* Rostov Oblast is conventionally considered as part of the Lower Don-North Caucasus Economic Region. In this discussion, however, Rostov is considered with the oblasts of the Lower Volga because spring wheat is the dominant seeded grain in Rostov Oblast.

The statistical method of describing the pattern of land use in the individual administrative districts of Region II loses much of its usefulness because a considerable part of each of the territories is made up of waste land or land on which target grains are seeded on scattered acreages. The greater part of the region is adjacent to the vast Asiatic desert, and light rainfall and chronic drought have tended to crowd much of the agricultural production against the western boundary of the region.

For example, Rostov Oblast (see the map and Table 23 in the Annex) has a total area of 10.45 million hectares, of which only 3.13 million hectares, or 30 percent, were seeded to target grains in 1938. These target grains, however, are distributed primarily throughout the general seeded acreage of only 4.64 million hectares, or 44 percent of the total area, lying chiefly in the western part of the oblast. The eastern part of the oblast is largely land unsuited to profitable field-crop production, and seeded acreages are widely scattered. The land-use pattern of this oblast is varied, with barren stretches in the area of the city of Rostov and in other scattered localities. It is not possible at this time to delineate the intricate land-use pattern within the limits of the total seeded area. Similar land-use patterns prevail in the oblasts of Stalingrad, Saratov, Kuybyshev, and Chkalov.

In the north, Bashkir ASSR (see the map and Table 30 in the Annex) has a total area of 14.35 million hectares, of which only 2.6 million hectares, or 18 percent, were seeded to target grains in 1938. These target grains, however, are distributed largely throughout the general seeded acreage of only 3.5 million hectares, or 24 percent of the total area, concentrated in the western and northwestern parts of the republic. About 76 percent of the republic is mountainous or covered with forests, pastures, and other land areas not well suited to field-crop production.

3. Region III.

Region III, in which rye (almost exclusively winter rye) and oats are the predominating crops, is made up of a normally grain surplus region (III-A) in the south of European USSR and a normally grain deficit region (III-B) in the north.

a. Region III-A.

Region III-A includes all of West Ukraine (except the Transcarpathian and Chernovitsy Oblasts); the North Ukrainian oblasts of Zhitomir, Chernigov, and Sumy; as well as the northern part of Kiev Oblast of North Ukraine. It also includes the Central Agricultural (Black Soil) Region,* as well as Chuvash ASSR and Tatar ASSR. This grain surplus region is characterized by winter rye as the most important of the target grains. The second most important crop is generally either winter wheat or oats. In North and West Ukraine, barley tends to be a more important crop than spring wheat, whereas in the Central Agricultural (Black Soil) Region the reverse tends to be the case.

Under normal growing conditions the acreage seeded in the potential target area of Region III-A in 1938 would have accounted for 18 percent of the production of all the target grains produced in the USSR in that year (see Table 1). The region would have produced 15 percent of the winter wheat, 9 percent of the spring wheat, 30 percent of the winter rye, 10 percent of the barley, and 20 percent of the oats. Under normal growing conditions the bread-grain production in the potential target area of Region III-A in 1938 would have been 18 percent of the total bread-grain production in the USSR.

The land-use pattern in most of the eastern half of Region III-A is more or less similar to that of North Ukraine. The country is generally open steppe with

* The Central Agricultural (Black Soil) Region includes the oblasts of Bryansk, Kursk, Orel, Voronezh, Tambov, and Penza, and Mordvin ASSR.

seeded acrages fairly uniform in their distribution, but wooded areas are more frequently encountered than in the south. Kursk Oblast presents at least a 37-percent statistical chance of a direct hit by a feather-bomb drop; Voronezh, 31-percent; Tambov, 34-percent; Penza, 33-percent; and so on. Toward the west the region is more heavily wooded, and the statistical chance of making direct hits on the oblasts in this area becomes less than in the east -- Chernigov, 23 percent; Zhitomir, 23 percent; Rovno, 22 percent; and so on.

Summarizing the situations in the grain surplus Regions I, II, and III-A, under normal growing conditions, the acreages seeded in the potential target areas of these three regions in 1938 taken as a whole would have accounted for 55 percent of the four target grains -- wheat, rye, barley, and oats -- produced in the USSR in that year (see Table 1). The three regions would have produced 81 percent of the winter wheat, 41 percent of the spring wheat, 57 percent of the winter rye, 64 percent of the barley, and 40 percent of the oats. Under normal growing conditions the combined bread-grain production in Regions I, II, and III-A would have been 59 percent of the total bread-grain production in the USSR.

This vast grain surplus region, which is the primary target for a BW attack on grains, has a total area of 775,000 square miles, of which 318,400 square miles, or 41 percent, were under field-crop production in 1938. Wheat, rye, oats, barley and barley were seeded on 215,300 square miles, or 28 percent of the total area.

Although, as pointed out in the discussion of Region II (the spring wheat region), the statistical approach to employing the land-use pattern as an indication of the percentage of chance of making a direct hit on one or another of the target grains by any single feather-bomb drop is, in some cases, invalid, nevertheless it would be the grain growing on this 28 percent of the total area of Regions I, II, and III-A that would be the target for a BW attack. In

the Ukraine and the Central Agricultural (Black Soil) Region the chances are considerably more than 28 percent. By avoiding the mountains and waste land areas of the North Caucasus region, the valleys of the Lower Don and the Volga rivers, and the mountainous and forested areas of the Urals Economic Region, the chances of making a direct hit would also be greater than the 28-percent average for Regions I, II, and III-A.

b. Region III-B.

The [redacted] districts in grain deficit Region III-B, on the other hand, offer relatively poor targets (less than a 28-percent chance) for successful feather-bomb drops. Vast forests cover the northern part of this whole region, and south of these primeval forests the region is characterized by marshes, pastures, and wooded areas, which in many oblasts are more uniformly distributed than are cultivated areas. Often these cultivated areas appear as "islands" scattered irregularly throughout lands that are not well suited to production.

The map [redacted] shows only part of [redacted] Region III-B, [redacted] European USSR. The northern limits of which extend above the Arctic Circle. Region III-B includes the Northwest Economic Region with Leningrad as a center; Northern European USSR with Arkangel'sk as a center; the Baltic Economic Region; Belorussia (west and east); Industrial Concentration B in Central European USSR with Moscow as a center; Velikiye Luki Oblast in the west; Kirov Oblast, Chuvash ASSR, and Mari ASSR in the east; and, finally, Udmurt ASSR and Molotov Oblast in the northern part of the Urals Economic Region.

Under normal growing conditions the acreage seeded in the potential target area of Region III-B in 1938 would have accounted for 22 percent of all the

target grains produced in the USSR in that year (see Table 1). The region would have produced 9 percent of the winter wheat, 8 percent of the spring wheat, 36 percent of the winter rye, 19 percent of the barley, and 36 percent of the oats. Under normal growing conditions the bread-grain production of the potential target area of Region III-B would have been 18 percent of the total bread-grain production in the USSR.

The target potentialities of Region III-B are poor, with the exception of Tula Oblast, with a 29-percent statistical chance of a direct hit on one or another of the target grains by a feather-bomb drop, and Ryazan' Oblast, with a 31-percent statistical chance. Smolensk Oblast presents only a 19-percent statistical chance of a direct hit by a feather-bomb drop; Kirov, 15-percent; Minsk, 16-percent; Moscow, 9-percent; Kalinin, 11-percent; and so on.

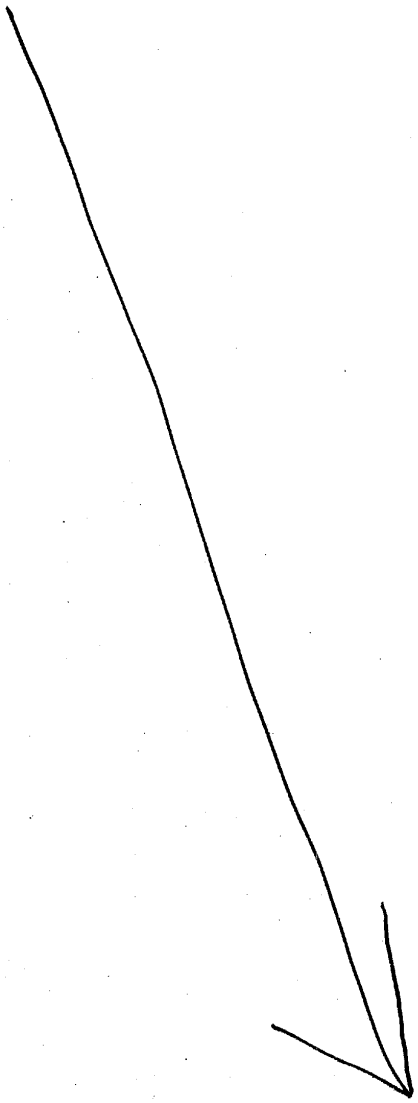
4. Region IV (Asiatic USSR).

The chief grain-producing region of Asiatic USSR, which produces a surplus of spring wheat and oats, ~~which produced about 10 percent of all the target grains grown in the USSR in 1938,~~ is a relatively narrow belt extending from the foothills of the Ural Mountains eastward to the foothills of the Altai Mountains.

Region IV ~~which produces a surplus of spring wheat and oats~~ includes all administrative districts for which data are given in Tables 88 to 99, inclusive, in the Annex. For the most part, this surplus area lies in the West Siberian Economic Region. The remainder of Asiatic USSR (which is not included in Region IV and comprising most of the Central Asia, East Siberian, and Far East Economic Regions, is deficient in the production of all grains. Neither Region IV nor the remainder of Asiatic USSR which is not included in the tables in the Annex), is shown on the map in this report, as the grain deficit therein is

often discontinuous and is dispersed to such a degree that The sowed grains unsatisfactory targets.

Region IV irregularly follows the 55th parallel of north latitude and includes Chelyabinsk Oblast and the southern part of Sverdlovsk Oblast of the Ural Economic Region. It also includes Kurgan Oblast; the southern part of Tyumen Oblast; parts of Omsk, Novosibirsk, and Kemerovo Oblasts; as well as the northern part of Altai Kray of the West Siberian Economic Region. The [redacted] belt also includes North Kazakhstan



Oblast and the northern parts of Kustanay, Kokchetav, and Pavlodar oblasts of Kazakh SSR.

Under normal growing conditions the acreage seeded in the potential target area of Region IV in 1938 would have accounted for only 13 percent of all the target grains produced in the USSR in that year (see Table 1). The region would have produced 34 percent of the spring wheat, 0.2 percent of the winter wheat, 5 percent of the winter rye, 4 percent of the barley, and 16 percent of the oats. Under normal growing conditions the bread-grain production in the potential target area of Region IV in 1938 would have been 13 percent of the total bread-grain production in the USSR.

Many of the rivers traversing Region IV take their rise in the Kazakh tableland and flow north to the Arctic Ocean. During part of the year their mouths are frozen, and their waters back up into the area of the surplus belt, creating extensive marsh lands bordered by areas suitable only for the production of grass. In fact, much of the grain can be grown only on "islands" of tilled land where the water table is sufficiently low to admit cultivation of field crops. Grain is grown extensively in the foothills of the mountains bordering the belt on the west and east, as well as in favorable valleys of the tablelands to the south.

The statistical method of indicating the land-use pattern is of questionable utility in such cases as Tyumen Oblast with 0.7 percent of the total area seeded to target grains in 1938, Sverdlovsk with 4 percent, Kemerovo with 3 percent, Kustanay with 3 percent, Kokchetav with 4 percent, and Pavlodar with 3 percent.

From dot maps based on seeded areas in 1938, it appears that the spring wheat and oats acreages in Kurgan Oblast are fairly evenly distributed. In Kurgan

Oblast, with a total area of 7.11 million hectares, only 1.74 million hectares were under target grains in 1938 as follows: spring wheat, 14 percent; winter rye, 3 percent; barley, 1 percent; oats, 6 percent; or 24 percent in all. Statistically, the grain in this oblast offers a fair target to a feather-bomb drop with a 24-percent chance of a direct hit. Grain in North Kazakhstan Oblast and the southern part of Omsk Oblast appears to have a concentration about the same as that in Kurgan. There is thus a strip of fairly heavily concentrated grain acreage extending about 600 miles from 65 to 75 degrees east longitude and 150 miles wide extending somewhat north and south of 55 degrees north latitude, or 90,000 square miles in all.

There appears to be considerable grain in Altai Kray, which has a total area of 26.16 million hectares with a total seeded acreage of 3.9 million hectares, or 15 percent of the total acreage. Scattered throughout this total seeded acreage, 3.3 million hectares were seeded to target grains in 1938, largely in three river valleys some distance apart. It is questionable whether the grain in Altai Kray or in any other part of Asia, except in the limited belt indicated above, offers a worth-while target for a BW attack on grain.

About 10 percent of all the target grains grown in the USSR are produced in other parts of Asia, in scattered areas throughout East Siberia and the Far East, in and about the oases of Central Asia and South Kazakh SSR, or in Transcaucasus. These areas probably are of only secondary interest or of negligible value from the point of view of BW attack.

B. Famine of 1932-33. 1/*

There is no authentic information available relative to the extent of stem-rust spread from a single focus of

* Footnote references in arabic numerals are to sources listed in Appendix C.

infection in the USSR or relative to the degree to which any rust damage has reduced yields. Otto Schiller, the former Agricultural Attaché of the German Embassy in Moscow, in discussing the agricultural crisis of 1932-33, which was attended by famine, mentions a stem-rust epidemic in that year in certain areas of the USSR. Since there has been considerable confusion in the minds of certain analysts as to the cause of the famine of 1932-33, the following discussion is given in some detail.

To understand the famine of 1932-33, it is essential to know that in 1930-31 grain production was "good" -- reported at 83.5 million metric tons, from which the Soviet Government procured 22.1 million tons, or 26.5 percent, leaving 61.4 million tons on farms. The deduction of the 6 million tons that were exported from the government's procurement of 22.1 million tons leaves the equivalent of 16.1 million tons for nonfarm utilization.

In 1931-32 there was a crop failure. Generally unfavorable growing conditions, including drought and hot winds from the Asiatic desert, destroyed a large part of the production [redacted] in the Volga Valley, in the Ural Region, and in West Siberia. Total grain production dropped to an estimated 66.1 million metric tons. In spite of the poor harvest the government exacted deliveries from farmers amounting to 22.8 million tons, or 34.5 percent. The government exported [redacted] 4.8 million metric tons of grain that year, which, deducted from the procurement of 22.8 million tons, leaves the equivalent of 18 million tons for nonfarm utilization. Because 22.8 million tons had been procured by the government from a production of 66.1 million tons, only 43.3 million tons were left on farms as compared with 61.7 million tons in 1930-31. Although famine conditions were not reported, the populations of the chief agricultural regions were faced with the problem of mere existence. Farm stocks

were depleted. Considerable numbers of livestock, including draft animals, were slaughtered, and in some areas farmers were forced to eat some of their seed reserves. It is reported that whole villages migrated from the worst stricken areas to seek better living conditions.

The seeding campaign for the harvest of 1932-33 was handicapped by a shortage of manpower and draft animals. There was also a shortage of seed because some had been consumed. The total grain acreage dropped 4.5 percent below that of 1931.-32. The drastic steps taken by the government in forcing excessive deliveries of grain in 1931-32 had greatly lowered the morale of the peasants. The hastily established collectives were poorly managed and badly organized.* Work in collective fields was poorly done, and the peasants tended to concentrate their energies on the cultivation of their own garden plots. Because the peasants could not or would not cope with the situation, weeds gained the upper hand, and often it was impossible to identify what kind of grain had been seeded in a field.

There were also heavy harvesting losses because work was performed too late. Much grain spoiled in the sheaf and shock in the fields. Finally mice appeared in large numbers in North Caucasus, in South Ukraine, in the Crimea, and in Kazakh SSR, destroying much grain in stacks and storage sheds. In addition to the foregoing factors tending to lower production, Schiller makes the following statement:

"Heavy rust damage appeared in certain areas in North Caucasus, in parts of the western side of the Lower Volga, in the Central Black Soil Belt, and in West Black Soil

* The great drive to collectivize 100 million peasants began in 1929. In March 1930, Stalin called a temporary halt, but the good harvest of 1930-31 was taken as an indication of the success of collectivization, and the drive was continued. By the middle of 1931, official statistics show that 13 million households, or 52.7 percent of the total, had been collectivized. The Ukrainians and the Cossacks living in the grain-producing regions had resisted collectivization, and the measures taken against them were ruthless, accompanied by marauding, arrest, and even slaughter of the better class of farmers, leaving the conduct of the collectivized land holdings in the hands of the poorer and less able peasants.

Ukraine" 2/ -- that is, in the oblasts west of the Dnepr River. In certain other districts of the Central Agricultural (Black Soil) Region and of the western side of the Lower Volga, 1932-33 harvests were better than in 1931-32. There were also better harvests in South Ukraine and the Crimea. Although the harvests in 1932-33 in the Volga, the Urals, and West Siberia were better than in 1931-32, the production could not be considered "good." In Central* and West European USSR,** in East Siberia, and Central Asia, an average production was obtained. On the other hand, production in the southern grain surplus regions of European USSR as a whole were poorer than in the previous year.

The weather conditions in 1932-33 were generally favorable, and, in fact, the production estimated at 66.4 million metric tons was slightly better in 1932-33 than in 1931-32 but about 20.5 percent below that of 1930-31. The government, however, again went onto the farms as though there had been no crop failure and exacted heavy deliveries amounting to 18.8 million tons, or 28.3 percent of the production.

During 1932-33 the government exported 1.5 million metric tons of grain, which, if deducted from the 18.8 million tons of procurements, indicates the equivalent of 17.3 million tons left for nonfarm utilization. This quantity was 3.9 percent below the nonfarm grain availability during 1931-32 but was 7.5 percent greater than during the good crop year 1930-31. Deducting 18.8 million tons of procurements from

* By [redacted]" Schiller means the former "Central Industrial Region," which conforms roughly to the modern "Central European USSR."
** "West European USSR," in this case, includes Kalinin and Smolensk oblasts and the oblasts of Belorussia (frontiers of 1937).

"Mittelrussland," 3/

the estimated production of 66.4 million tons indicates that the farm population had about 47.6 million tons to carry them through the consumption year 1932-33. Although, taking the USSR as a whole, this total is 4.3 million tons [redacted] left on farms in 1931-32, the distribution was irregular, with somewhat better availabilities in Asiatic USSR and in the central and northern parts of European USSR. The southern grain surplus regions suffered, and millions of the rural population, particularly in the Ukraine and Lower Don-North Caucasus Economic Regions, starved to death.

The situation in the USSR in 1932-33 brings out certain [redacted] fundamental facts, as follows: 1. Although the grain production in 1932-33 was reduced for the second year, 20 percent below the good crop year 1930-31, the equanimity of the Kremlin was not disturbed. The government stripped farms of nearly the same quantities of grain for nonfarm utilization as in preceding years and, although millions of people were starving, ruthlessly exported 1.5 million metric tons of grain.*

2. It is possible for a stem-rust epidemic to spread over parts of the southern grain surplus regions of European USSR. I, II, and III-A. There is, however, no evidence indicating the extent of the spread or the intensity of the damage caused by the infection.**

It must be borne in mind that the success of a BW attack on Soviet grain with feather-bomb drops will depend very largely on the extent of the stem-rust spread grids and the intensity of the destruction, within these grids, of the wheat, rye, barley, and oats growing in the three grain surplus regions of European USSR at the time of the attack.***

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* In a previous report, CIA/RR 5, [redacted] A Preliminary Appraisal of the Effects of a Biological Attack on Grains in the USSR, an effort was made to assess the effects on Soviet economy attending each of three loss patterns of the grain most susceptible to rust. In discussing the first of these three loss patterns, it was concluded that if as a result of a BW attack on Soviet grain a 20-percent loss of all the wheat, rye, and oats and a 10-percent loss of all the barley produced in the USSR were sustained, the effects on the Soviet economy would be relatively small even in the second year of such an attack.

** It should be noted, however, that in two of the regions in which heavy stem-rust damage was reported the production was better in 1932-33 than in 1931-32. These regions are the Central Agricultural (Black Soil) Region (Region III-A) and the western part of the Lower Volga Valley (Region II).

*** An analysis of evidence based on US experience with stem-rust spread follows in Part II of this report.

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[redacted]

PART II

PRELIMINARY STUDY OF [redacted]
PROBABLE ~~SPREAD OF STEM RUST~~ STEM-RUST SPREAD ON CEREAL GRAINS*

A. Problem.

To estimate on the basis of recorded instances of cereal stem-rust spread from infected barberry bushes in the US the areal extent which disease of damaging [redacted] proportions might be expected to reach following a single drop of the currently available BW munition.

B. Conclusion.

In spite of limitations imposed in comparing stem-rust spread from barberry bushes with that from a munition drop, it is apparent that heavy damage over an area of not less than 100 square miles can be expected from each successfully established focus of infection resulting from BW attack with stem rust early in the growing season, given a susceptible variety of grain and at least reasonably favorable ensuing weather conditions.

C. Discussion.

1. Scope of Inquiry.

The success of overt attacks aimed at establishing cereal stem-rust spread [redacted] of epidemic proportions is dependent on the same complex of time-weather factors which govern the development of natural epidemics. At the present time, data on all the factors in this complex, as related to natural epidemics, are inadequate for an accurate assessment of the development and spread of stem rust which might result from the artificial establishment of a single focus of infection. Within imposed time limits, full use has been made of available data on the natural spread of cereal stem rust from barberry bushes in the US (see Appendix A).

In connection with the barberry eradication program of the US Department of Agriculture, some 1,528 case histories of stem-rust spread from infected barberry bushes were compiled. The great majority of these case histories, over 90 percent, represent very limited spreads from small local focal points of infection, [redacted] obviously limiting their usefulness for the purpose of this survey. This limited spread may have resulted from one or more of several factors, as follows: (a) only one small bush or at best a few small bushes in a restricted area were

* Prepared by the Office of Scientific Intelligence.

[redacted]

involved; (b) the barberry bushes were only moderately infected; and (c) considerable distance intervened between barberry bushes and susceptible grain or grasses. Because these histories were collected during the course of barberry eradication work, many were taken two or more weeks before crop maturity and so do not give an accurate picture of total spread or final severity.

Some 132 cases, or 8.5 percent of the total, were selected as representing spreads of more than 1 mile. In the selected group are found examples from every kind of terrain and most of the broad land-use patterns under which small grains are grown in the US. The survey also includes, insofar as there are parallel conditions in the US, all of the climatic variants likely to be important in a target area.

2. Findings.

a. Of the 132 cases where stem-rust spread extended more than 1 mile, 28 were dramatic, ranging from 50 up to 2,260 square miles. Heavy damage in these instances covered from 5 to 250 square miles, depending on time and other factors, such as the amount of susceptible crops near the focus of original infection.

b. Presence of abundant early inoculum was common to all of the more dramatic spreads. The number of barberry bushes was less important than their size and the heaviness of infection. The distance of the barberry bushes from the susceptible crop has an important effect in determining the amount of original infection on the crop and the subsequent build-up and spread.

c. Stem-rust spread from local foci of infection has occurred under the full range of geographical location, climate, and terrain characterizing 18 states of the US in which barberry eradication has been conducted.

d. Land-use pattern — that is, proportion of land in total farms, cropland, pasture, and woodland, where this last does not exceed 25 percent scattered through cropland — does not seem to limit the spread of stem rust. When intensive infection is established on small grain, extensive spread is possible even though fields of susceptible small grain are scattered among nonsusceptible crops.

e. In open plains or rolling country, spread will go in any direction, controlled only by winds. In valleys, heavy infection patterns, probably influenced by diurnal air movements, often follow drainage lines. Woodland which is near or which completely surrounds barberry bushes has some effect in reducing build-up. Stem-rust spread was rarely symmetrical in the case histories reviewed, being commonly fan-shaped or some modification thereof, extending away from the focus of infection in the direction of prevailing winds.

3. Limitations Imposed by the Nature of the Survey.

The survey here reported is of a preliminary nature and will be supplemented, within a year, by the findings of work now under way, part of it in the field. In view of this and of the nature of the material employed, it is essential to stress the following specific limitations in order that the findings be correctly evaluated:

a. The case histories which furnish the basis for this survey were developed primarily for educational and demonstration purposes and in the great majority of instances contain little data other than the extent of stem-rust spread from one or more barberry bushes which may have served as a primary source of inoculum. In some cases a general statement is made as to rust severity and grain loss. General statements on yields are occasionally given, but, on the whole, there is no very valid basis for estimating the extent of damage.

b. Time limitations have precluded the study of certain factors which should be taken into consideration in such a survey. Weather during the seasons and in the localities involved, the most important of these factors, has not been taken into account, nor has there been considered the relative earliness or lateness of the season as it influences the time for build-up of inoculum.

c. As noted above, available data were customarily taken at the time of barberry destruction work, considerably before actual harvest time. These data often represent a very much smaller total effect than that actually experienced.

d. It has not been possible to develop any satisfactory way of translating stem-rust spread occurring from the more or less concentrated yet limited foci of barberry bushes into what might be expected from the larger, and originally more diffuse, centers developing from feather-bomb drops. Case No. 11, Appendix A, most closely parallels the overt BW attack.

e. Presently available data are not adequate to predict with accuracy the square-mile area in which a crop loss of 50 percent will occur as a result of stem-rust spread from a successfully established infected area of 1 square mile (the problem originally proposed). The historical record of rust development in eastern Manitoba during the years 1929 and 1935 illustrates this fact. The former was a year of "light" rust; the latter, "very heavy."* Data comparing dates of crop heading, occurrence of spore showers, earliest and light general infection, and general harvest, together with the amounts of spore fall and final amounts of rust, are given in Table 2.**

* With one exception, in which "heavy" damage was defined as 20 percent or more, there are no percentage values equivalent to the terms "heavy," "moderate," "light," and the like

** Table 2 follows p. .

"very heavy." (see Case No. 5, Appendix A)

Table 2

Record of Stem-Rust Development
in Eastern Manitoba
1929 and 1935

Year	Dates of Occurrence of Spore Showers	Number of Spores per Square Inch	Dates of Infection: Earliest	Dates of Infection: Light General	Date of General Harvest	Amount of Rust
1929	14 to 18 June	326	3 July	3 to 10 July	8 August	Light
1935	24 to 30 June	365	3 July	3 to 10 July	8 August	Heavy

Weather during the period from heading to harvest was clearly the determining factor. (See Appendix B.)

4. Implications with Respect to Biological Warfare Operations.

While recognizing the above limitations, the several records of spread from stem-rust barberry bushes presented in Appendix A show positively that, under a wide variety of conditions as to terrain, geographical location, and season, a destructive spread of varying extent will occur when a central source of inoculum is established. It is believed that careful meteorological analysis of target areas, with current utilization of meteorological data and 3- to 5-day forecasts, will remove many elements of uncertainty from operations.

The failure of significant spread in over 90 percent of the case histories emphasizes the necessity for large amounts of early inoculum which, by infecting a sufficiently extensive area, builds up the immense quantities of inoculum required for major epidemic spread. As an alternative, suggests a large number of relatively closely spaced, smaller foci from which spreads will coalesce. One case, in Goodhue County, Minnesota, (not included in the series of examples cited in this summary), illustrates such a situation. In this case a spread covering one township was formed of the coalesced small spreads from some 40 or more scattered foci. Intensive research is therefore necessary (a) to determine whether operational spore distribution should be diffuse over an entire area so as to form numerous relatively closely spaced, small foci or in more massive concentrations regularly distributed at intervals of several miles and (b) to perfect munitions designed most effectively to achieve optimum spore distribution.

In nature, those spore showers which establish original infection commonly extend over periods of time and occur at intervals of several days each. Hence,

in connection with a BW operation, the number of drops necessary to give reasonable assurance of an adequate initial infection must be determined.

The pattern of munition drop must take into account the unsymmetrical nature of the hoped-for spread in relation to wind and topographic features. It seems that land-use patterns will not materially affect development within wide limits.

The Pine Camp test of the currently available crop BW munition achieved primary infection over an area of 25 square miles. The early establishment of such a focus should result in a build-up and heavily damaging spread over at least 100 square miles. Actual experience in 1946 in Adams, Cumberland, and York counties, Pennysylvania, indicates that, in a favorable season, spread from a focus smaller than that reasonably expected from a BW drop covered 600 square miles, with 250 square miles of heavy damage. Recognizing that this heavy damage spread is not to be expected under average conditions, it seems conservative to plan on the basis of 100 square miles. If weather conditions are so unfavorable that this result is not achieved, it is one of the calculated risks that must be taken.

APPENDIX A

SUMMARY OF ELEVEN CASE HISTORIES OF STEM-RUST SPREAD IN THE NORTHERN PART OF THE U.S.

In studying the interrelations of land-use pattern, terrain, and general climate in [redacted] stem-rust spread, 28 studies of case histories showing extraordinary spread were analyzed. These were representative of at least four types, as follows:

(1) Level to gently rolling areas where a high proportion of all land was in cultivated crops, where grain crops occupied more than 20 percent of all land, and where woodland was less than 5 percent;

(2) Topographically similar areas where the proportion of all land in cultivated crops was 60 percent or less, where mixed cropping was general, where grain crops occupied less than 20 percent of all land, and where woodland was 0 to 10 percent;

(3) Wide stretches of rolling terrain, only a very small part of which was cropland and the remainder of which was an unimproved treeless expanse, with grain fields generally scattered widely; and

(4) Mixed farming confined to intermountain valleys, interspersed with woodland, with grain crops occupying 5 to 20 percent of the total cultivated area.

The geographic range of these studies includes northeastern Washington, Montana, Wyoming, Colorado, Nebraska, North Dakota, Minnesota, Iowa, Missouri, Wisconsin, Indiana, Michigan, Pennsylvania, and West Virginia. Summaries of 11 considered examples follow.* [redacted]

1. Rice County, Minnesota, 1922.

In Rice County, according to the 1925 census, cropland made up 59.1 percent of the total area; small grains, 24.2 percent; pasture, 19.2 percent; and woodland, 8.7 percent.

Centering about the town of Northfield, at distances of 1 to 6 miles, were seven groups of barberry bushes from which stem-rust spread extended to the surrounding area in 1922. The average date of first infection of grains from aeciospores in Minnesota is 24 May. A map showing distribution as of 10 July, about 7 weeks later, indicates that the entire area within four townships (144 square miles) carried a stem-rust infection ranging from "heavy" in the area nearest to the barberry bushes to a "trace" in areas farthest away. The average date

* For presentation in tabular form, see Table 3, p. [illegible], below.

(Typist—note footnote will follow at end of text of Appendix A)

for spring wheat harvest in the area is 1 to 11 August, so that 3 to 4 weeks still remained prior to harvest. Winter wheat, on the other hand, was approaching maturity, while oats had approximately 3 weeks to go. On 10 July the map indicates that stem rust was "heavy" in 19 square miles, "moderate" in 38 square miles, and "light" in 72 square miles, with a "trace" infection in the remainder of the 144 square miles (leading off the map).

During the interval before harvest, "moderate" infection built up to the "heavy" level, and a large part of the entire 144 square miles developed a very seriously damaging epidemic, the total spread reaching 315 square miles. Data are not adequate on which to make a firm estimate of the area in which damage reached 50 percent of the crop.

2. Faribault County, Minnesota, 1926.

In Faribault County in 1925, farms made up 70.7 percent of the total land area; grain crops, 27.1 percent; and woodland, 2.5 percent.

In 1926, some 70 barberry bushes growing in the vicinity of Rice Lake served as an infection center for the spread of stem rust. A map, dated only as "July," covers 12 townships in which rust is shown over the entire area in varying degrees of intensity. Approximately 66 square miles are indicated to be "heavy"; 184 additional square miles, "moderate"; and the remainder of the 432 square miles, or 182 square miles, as a "trace" to "light." A report, apparently of a later date, states that stem-rust spread to wheat was "heavy" over the entire eastern half of the county, or 360 square miles. The inclusion of this later statement suggests that the data for the map were collected before harvest, but how long before is not indicated. No data are available on which to make a firm estimate of the area in which damage reached 50 percent of the crop.

3. Barnes County, North Dakota, 1925.

Barnes County is typical of the Northern Great Plains. In 1925, cropland made up 71.2 percent of the total land area; grain, principally wheat, 44.4 percent; and woodland, less than 1 percent.

Two groups of barberry bushes lying about 6.5 miles apart -- one 6 miles northeast of Valley City and the other 9 miles east -- served as focal points for stem-rust spread in Barnes County. One contained 15 bushes, and the other 10. A map dated only "August 1925," which probably indicates stem-rust spread at harvest or shortly before, harvest being 1 to 11 August in that area, shows coalescence of spread from the two foci. An area of "heavy" infection scales out something more than 20 square miles; "moderate" infection, 80 square miles; and "light" infection, 80 more square miles. The statement is made that, within 1 mile of

the first group of bushes, yields were between 6 and 11 bushels per acre and graded No. 3 and that at corresponding distances from the second group yields ranged between 7 and 9 bushels per acre of a corresponding grade. The statement suggests a probable reduction in the heavily infected area ranging from 20 to 40 percent depending on distance from the primary infection foci. There are no other data suggesting the degree of actual loss.

4. Grand Forks and Traill Counties, North Dakota, 1928.

These counties are typical of the Red River Valley. The terrain is level, and woodland occupies less than 2.5 percent of the total land area of both counties. In 1929 the percentage of all land in small grains was 38.8 in Grand Forks County and 43.9 in Traill County.

Two large barberry bushes, 9 feet high and with a spread of 107 square feet, located in Grand Forks County, were the center of a stem-rust spread in the two counties. Both bushes were very heavily infected. Spread to grains probably began in late June. Observations in August, presumably at about wheat harvest, showed a spread fanning out more than 10 miles to the southeast. Spread to the east reached the Red River, a distance of about 2.5 miles. The pattern of spread indicated continuation across the state line into Minnesota, but no observations were noted for that state. In North Dakota the map indicates a spread ranging in severity from "heavy" to "light" infection over an area of 55 square miles. Of this spread, some 12 square miles were indicated to be "heavy"; about an equal area was indicated to be "moderate", and the remainder "light." The pattern of spread suggests an added area in Minnesota approaching in size that in North Dakota. Although 1928 was a year of light stem rust in the north-central states, the amount and distance of spread in this instance indicates that conditions for the establishment and development of stem rust, at least in the Red River Valley, were favorable enough to create a destructive epidemic spread for at least 25 square miles, with less damage over a wider area. No data are available on which to ~~base~~ make a firm estimate of the area ~~within~~ in which ~~crop~~ damage ~~equalled~~ reached 50 percent of the crop.

5. McLean, Sheridan, Burleigh, Oliver, and Morton Counties, North Dakota, 1929.

These counties are located along the Missouri River in the west-central part of the state. The area concerned, immediately northwest, north, and northeast of Bismarck, is typical of the Northern Great Plains. Taking Burleigh, Morton, and Oliver as typical, according to the 1930 census, cropland made up approximately 40 percent of the total land area of each county; small grains, approximately 24 percent; and woodland, less than 1 percent.

two

In August 1929 the stem-rust spread from A groups of barberry bushes, one of 12 and the other of 16 bushes, was mapped. The two groups were situated 2 miles apart, near the west bank of the Missouri in eastern Oliver County. A survey made in the week of 8 August showed a total spread, ranging from "light" to "heavy," covering some 2,260 square miles. Of this total, approximately 215 square miles were rated "heavy"; 245 square miles, "medium"; and the remaining 1,800 square miles, "light." Outside the 2,260-square-mile area, all grain was indicated to carry a "trace" of rust. Since 1929 was a year of "medium" stem-rust damage in the north-central region, a general sprinkling of stem rust would be expected by 8 August over most of North Dakota, including this area, even though it is outside the section where greatest damage occurred from the general epidemic of that year. In these counties the principal stem-rust damage was caused by the spread from the barberry bushes. No data are available on yields or extent of damage by field or areas. The survey was made by an experienced individual, however, and elsewhere in his surveys, "heavy" indicates damage ranging from 20 percent up.

6. Kit Carson County, Colorado, 1922.

~~This county~~ Kit Carson County is typical of the high plains of eastern Colorado and northwestern Kansas. The topography is that of the rolling plains. In 1922, much of the land was still undeveloped. Cropland made up only 14.3 percent of the total land area; small grains, 6.2 percent; and woodland, all of which was along stream valleys, less than 2 percent.

Twelve heavily rusted barberry bushes in the town of Burlington provided the primary stem-rust inoculum. [redacted] the average date for the first appearance of rust infection on grains and grasses from barberry ~~spread~~ bushes in Colorado was 2 June. By 26 June a "moderate" infection on grasses and grain extended one-half mile from the bushes; "light" infection, 1 mile; and a "trace," beyond 2 miles. Final reports indicated that in the 3 to 5 weeks before harvest, depending on whether the crop was winter wheat, spring wheat, or oats, the spread had extended 20 to 25 miles from the bushes, with a severity rendering many fields unfit for harvest. The final report gave no estimate of total area of spread or of the area within which damage was severe.

7. Decatur County, Indiana, 1922.

~~This county~~ Decatur County is representative of the slightly rolling topography of the east-central states. According to the 1920 census, [redacted] cropland made up 51 percent of the total land area; small grains, some 16 percent (or approximately 30 percent of all cropland); and woodland, slightly less than 10 percent.

One very large barberry bush, probably 60 years old, was the center of infection for an extensive spread. The average date of first infections on grains from barberry bushes in Indiana is 17 May. By 1 July the average date of the winter wheat harvest, severe infection had spread to 50 square miles. The usual yield of wheat in the area at that time was about 22 bushels per acre, which was cut to an estimated 8.8-bushel average, or, considering reduced bushel weight and poorer quality, more than 60-percent damage. How much farther the spread extended with less damage was not recorded.

8. Laramie and Platte Counties, Wyoming, 1920.

The area in these two counties in which the spread occurred is typical of the rolling high plains. In 1920, only limited land had been broken out, and cropped and grain fields were few and far between. In the two counties, according to the 1920 census, the percentage of the total area in grain crops was only 3.9 percent in Laramie County and 1.9 in Platte County.

A barberry hedge surrounding a park in the city of Cheyenne was the center of a rather long-range spread in 1920. Fields some 42 miles north of Cheyenne were rusted from 20 to 35 percent, and at 80 miles north at Wheatland, 10 to 20 percent. At the same time, wheat at Pine Bluffs, 45 miles east of the barberry bushes, was pastured off as not worth cutting. Similar spreads occurred in 1921 and 1922, the bushes being removed in the latter year. The widely scattered occurrence of wheat and other grain fields did not give opportunity for extensive early season build-up close to the bushes and therefore gave no criterion of the area of "heavy" damage.

9. Flathead County, Montana, 1942.

The area involved was the Flathead Valley in western Montana immediately to the north and west of Flathead Lake and west of the Continental Divide. Farmland in Flathead County is practically all confined to this valley. Of the farmland, cropland (one-third in small grains) made up 31.5 percent; woodland, 45 percent; and pasture, the rest. Much of the cropland, however, is contiguous.

Two barberry bushes within 100 feet of a field of winter wheat located just west of the town of Big Fork were the center of infection. On 1 July, when wheat was flowering, only 4 weeks before harvest, stem-rust spread was fanning out in the wheat. A map prepared at the end of the season showed a "heavy" infection extending over 4 square miles, "moderate" infection over four additional square miles, a "light" spread over [redacted] more square miles, and a "trace" over

the remainder of the 216 square miles that were mapped. This spread was very significant, considering the short time involved. No data are given on yields on which to make a firm estimate of ~~as a base for estimating~~ the area [redacted] in which damage reached 50 percent of the crop.

10. Monroe County, West Virginia, 1943.

Monroe County ~~[redacted]~~ is in the mountainous country of southeastern West Virginia. A series of interconnecting mountain valleys with valley farmlands and hillside woodland and pasture is characteristic. Only about 20 percent of the land in farms is cropped, and about 20 percent of the cropland is in small grain. Woodland occupies about 30 percent of all farmland.

On a map of the area, barberry bushes are shown at nine points along a 5-mile stretch running southeast from the intersection of Greenbrier, Monroe, and Summers counties. Stem-rust spread was principally in Wolf Creek and Second Creek townships. The survey map, dated 16 June, indicates a "very heavy" infection over some 17 square miles, "heavy" over [redacted] 8 more square miles, and "moderate" over at least ~~50~~ 50 additional square miles. As mapping was stopped at geographic and other boundaries with no apparent relation to stem-rust spread, the extent of total spread cannot be determined. At the time when the crop was in the medium dough stage, rust severity ranged from [redacted] 100-percent prevalence and 80-percent severity to 50-percent prevalence and 10-percent severity at the more distant points. Some 10 days remained before harvest, and these degrees of severity undoubtedly built up to more destructive proportions. No data are given on yields, but the rust readings suggest at least a 50-percent yield reduction from 10 to 15 June in the 25 square miles of "very heavy" and "heavy" infection.

11. Adams, Cumberland, and York Counties, Pennsylvania, 1946.

These counties, located in south-central Pennsylvania, represent an intensively farmed, productive area of moderately rolling terrain. There are a number of streams, draining generally northeast toward the Susquehanna River. In these counties, 76 percent of the total land area was in farms in 1946. About 63 percent of this farmland was in crops, of which grain crops made up one-third. Woodland occupied some 15 percent of the total land area.

Some 1,200 or more barberry bushes, of which about 50 large ones were strategically located near grain fields, all within a square-mile area, were the primary center of an extensive stem-rust spread in 1946. The stem-rust spread extended irregularly with a rough conformity to drainage patterns in all directions, but more particularly to the east, went, and north. The spread covered about 35 miles east to west and 30 miles north to south. An area

approximating 600 square miles was generally infected. In some 250 square miles the damage was heavy. Farm yields were obtained on one leg to the east of the infection center in the most heavily damaged area. These yields ranged from reductions of 20 [redacted] to 45 percent. A thresher operator in the area reported that the average yield for the area which he served in this heavily infected section was 20 bushels per acre as compared with an average of 30 bushels in normal years -- an over-all reduction of 33-1/3 percent. If this reduction be accepted as average for "heavy" infection, it probably meant at least a 40-percent loss for half of the wheat in the 250-square-mile area.

Table 3

Selected Cases of Spread of Stem Rust in Specified Areas of the United States

Case No.	Location	Date	Number and Location of Barberries	Land-Use Pattern (Percent): Cropland	Grain	Woodland	Average Date of Initial Infection	Date Damage Examined	Area of Damage (Square Miles): Heavy	Moderate	Light	Trace	Total	Other Indications of Degree of Loss
1.	Rice County, Minnesota	1922	7 groups barberries, 1 to 6 miles from Northfield	59.1	24.2 (small grains)	8.7	24 May	a) 10 Jul b) Harvest time	19 "Large part of 144"	38	72	15	144 315	Data not adequate to make firm estimate of area in which damage reached 50 percent of crop.
2.	Faribault County, Minnesota	1926	70 barberries near Rice Lake	70.0 (in farms)	27.1	2.5	N.A.	a) "July" b) "Later date"	66 360	184	182		432	Data not adequate to make firm estimate of area in which damage reached 50 percent of crop.
3.	Barnes County, North Dakota	1925	2 groups, miles apart (25 bushes)	71.2	44.2 (mostly wheat)	1.0	N.A.	"August"	20	80	80		180	Probable reduction in "heavy" area of 20 to 40 percent depending on distance from primary infection foci.
4.	Grand Forks & Traill Counties, North Dakota	1928	2 large heavily rusted barberries in Grand Forks County, 2½ miles from Minn.		38.8 43.9	2.5	Probably late Jun	Aug at above harvest	12	12	31		55	A year of light rust generally; probably spread to an area about equal size in Minn. cannot estimate area with [illegible]
5.	Counties, North Dakota	1929	2 groups, (12 16 bushes), 2 miles apart, west-central North Dakota on the Missouri River	40.3	24.0	1.0	N.A.	8 Aug	215	245	1,800	(grain outside this area had a "Trace")	2,260	"Heavy" indicates damage a year of medium rust damage.
6.	Kit Carson County, Colo.	1922	12 heavily rusted barberries in Burlington	14.3	6.2	2.0	2 Jun	26 Jun		"Extended mile"	"Extended 1 mile"	"Extended beyond 2 miles"	N.A.	